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THE ANALYSIS OF INSTRUCTIONAL OBJECTIVES. DRAFT.

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THIS PAPER DISCUSSES AIMS, EFFECTS, AND IMPLICATIONS OF SPECIFYING OBJECTIVES FOR PROGRAMED INSTRUCTION, AND CITES EXAMPLES FROM THE LITERATURE. THE PAPER WAS READ AS A PORTION OF THE SYMPOSIUM ON PROGRAMMED INSTRUCTION, NATIONAL EDUCATION ASSOCIATION, WASHINGTON, D.C., MARCH 24-26, 1963. (LH)

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THE ANALYSIS OF INSTRUCTIONAL OBJECTIVES

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The changes in ways of viewing the process of instruction occasioned by the consideration of the techniques of auto-instructional programming are many, as other contributors to this symposium have shown. One of these changes pertains to an emphasis on defining instructional objectives, which is generally considered to be a matter of critical importance in the design of effective instruction.

Virtually all writers who have attempted to describe the factors to be taken into account in designing instructional programs have paid some attention to the defining of objectives. Skinner (1961), for example, describes this as a first step in the design of programs, and in another paper (1959) considers a variety of objectives which might be intended in the programming of verbal knowledge. Discussions of programming techniques which contain emphases upon defining objectives as an initial step include those of Cook and Mechner (1962), Evans, Glaser and Homme (1962), Gagné and Paradise (1961), Goldberg (1962), Green (1962), Mager (1961), and Klaus (1962). Stolurow (1961, pp. 85-102) devotes considerable attention to this subject in his review of concepts and techniques. The mathetics technique, as described by Gilbert (1962), is based upon the operation of "prescribing a mastery repertory," a phrase which may well be considered to give precision to the more widely used "stating instructional objectives."

Two sets of authors in the field of research on auto-instructional methods have given more extensive consideration to the problem of defining

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the objectives of instruction. Mager's book (1962) is a most convincing and useful essay on the subject, prepared in the form of an intrinsic program, which should be of great value to teachers and designers of instructional programs of any type. Taber, Glaser and Schaefer (1962, pp. 67-84) have contributed a critical discussion of a number of ways of viewing the problem, as well as its relation to the question of sequencing the instructional material, and to the broader problem of developing a taxonomy of performance objectives.

It is of some importance to note that besides the teaching machine movement per se, there are at least two other historical roots to the specification of instructional objectives as a practical technique and as a research problem. One of these centers upon an interest in the measurement of achievement in education, and is the culmination of many years of effort in this area beginning at the University of Chicago, and later spreading to other universities in the midwest. The responsibility for devising university-wide examinations in a variety of subjects forced the examiners, together with the faculty, to face squarely the hard fact that achievement measures cannot be sensibly designed until the course instructor states the objectives of his course. Furthermore, such statements need to be made in terms which imply some specific type of observable behavior, in order for measures to be constructed. The point of view which developed from this continued effort is presented by Tyler (1949). The taxonomy of objectives which was developed in this setting is discussed with examples by Bloom (1956), and recent experience with this system of specifying college examinations has been collected in a book by Dressel (1954).

The second source of research and development emphasis on the description of objectives as an initial step in instructional design comes

from programs of research on military training, particularly the training of Air Force technicians. This is evident in reviews of research oriented to the training of military personnel, such as those of Gagné and Bolles (1959) and Briggs (1959). It is specifically referred to in such studies of training effectiveness as those of Briggs and Besnard (1956) and French (1956). In the earlier writings of Miller (1953) and Gagné (1955) the specification of training objectives is conceived to be accomplished by means of a technique of broad usefulness in the development of personnel subsystems for man-machine systems, namely, by task analysis. The use of this technique results in the statement of training objectives in behavioral terms.

The Reasons for Specifying Objectives

Why is it considered an important step in the design of instruction to describe and analyze instructional objectives? Many writers have simply stated that this must be done before a program can be constructed, and left it at that. Some, however, either clearly state their reasons for considering this an essential step, or else they imply their reasons in more or less unmistakable fashion.

Revealing the Nature of the Terminal Behavior to be Learned

There is virtually unanimous agreement that an important reason for specifying objectives is so that the terminal behavior which is aimed for can be known to the instructional designer. In order to have a hope of success, the designer must know the nature of what must be learned. As Mager (1962) points out, a statement of an objective like "knowing how an amplifier works" is quite insufficient to provide this information, since the word "know" is ambiguous. (It might mean drawing a picture of an amplifier, or building an amplifier, or describing the purpose of components in an amplifier, or several other things). Additional examples of

the ambiguity of commonly used phrases in conveying the true meaning of an objective are given by Taber, Glaser and Schaefer (1962, pp. 67-84) and by Stolurow (1961), among others.

At the very least, the reason for knowing the nature of the terminal behavior is in order that the instructional designer can plan properly the final sequences of his program. While much learning may have taken place in an instructional program, there will be no proof of this unless the designer and the user are agreed upon what the learner will be able to do after he has been through the instruction. "What the learner is expected to be able to do" is the key phrase. The latter parts of the program can be designed to go in any of several directions--to aim at any of several forms of terminal behavior. Accordingly, they can be designed to establish in the learner some particular capability, agreed upon as an instructional objective. The designer wants to choose the acceptable course for arriving at this terminal behavior. Therefore he must have a statement about the sort of human performance which is overtly observable.

Besides determining the terminal sequence of the program, the behaviorally defined objective has another related function. Because of its unambiguous nature, it can constitute a basis from which inferences can be made by the instructional designer about the kinds of behavior modification required throughout the program, not only within its final portion. Further attention will be devoted to this function in a moment; it is mentioned here to provide a further appreciation of the utility of unambiguous definition of objectives.

Specifying Post-Learning Behavior for Measurement

An equally good reason for the specification of instructional objectives in terms of observable human performance, concerning which there

is again wide agreement, is to meet the requirements of measurement. An instructional program has the aim of establishing the capability for certain kinds of behavior; the learner must be able to do something after completing the instruction that he couldn't do beforehand. To know whether a program has fulfilled such an aim, it must be possible to observe, or in a more refined sense to measure, this post-learning behavior. Here also, then, is a reason why the objectives of the instruction must be specified in terms which imply reliable observability. Whatever capability of the learner cannot be specified in such terms, so likewise that capability cannot be measured. Mager (1962) emphasizes, in addition, the need for including in the objective statement an indication of minimally acceptable performance, in order that measurement can include considerations of "how well" or "how much."

Meeting the requirements of post-learning measurement is naturally given much prominence in the discussions of objectives contributed by those who have been primarily concerned with the design of tests to measure student achievement. When the intentions of many college teachers were put into the concrete form of test items, often after lengthy discussion, it was found that they reflected a great variety of objectives which Bloom (1956) describes under the general headings of knowledge, comprehension, application, analyses, synthesis, and evaluation. These category names themselves, however, appear to have little operational meaning, and in that sense contrast markedly with the many particular examples of actual test items which Bloom provides. For example, "comprehension" is in one instance measured by items designed to test "the ability to distinguish consequences which are only relatively probable from those for which there is a high degree of probability" (Bloom, 1956, p. 96). Thus, although the language used in this work does not

always meet the criterion of reliable identification of observable behavior, there can be little doubt that this movement in educational measurement has actually accomplished a great deal in the effort of specifying instructional objectives.

Distinguishing the Varieties of Behavior Which Can Be Modified by Instruction

A third reason for defining objectives which has often been mentioned is that of drawing distinctions among the different classes of behavior to be established, as a basis for inferences concerning how modification of pre-existing behavior can be undertaken. Actually, this may turn out to be the most important reason for describing objectives, although it has not always been stated clearly. What is intended is nothing less than the definition of certain classes of terminal behavior (such as discriminations, chains, etc.) each of which, regardless of its specific content, carries a particular set of implications for the conditions of learning required for its establishment. For example, if it is known that the learner must be able to discriminate among ten printed foreign words when instruction has been completed, this has a certain implication for the conditions of learning as they are built into an instructional sequence. Furthermore, it is quite a different implication that is the case for the establishment of a capability to reproduce orally a particular chain or sequence of ten foreign words.

The attempt to distinguish classes of terminal behavior having different implications for the design of instruction has led to a great variety of schemes for suggested categorization. Tyler (1949) states the problem as one of relating objectives to the types of learning experiences provided by the curriculum, but proceeds only to suggest, rather than specify, what these learning experiences may be. Perhaps the most thoroughgoing elaborations of this basic idea have been developed in

the setting of military technical training as reflected in the writings of Miller (1956 b), Gagné (1962), and Glaser and Glanzer (1958) among others. In connection with programmed instruction, Stolurow (1961) discusses the distinguishing characteristics of tasks which were originally proposed by Cotterman (1959). The mathetics approach of Gilbert (1962) places emphasis upon three major categories of behavior for which differential treatment is to be prescribed: chains (including mediating chains), multiple discriminations, and generalizations. Evans (1961) distinguishes two major categories, for which different learning techniques can be developed, as "classes of discrimination" and "functional relationships between these classes." The existence of these various approaches makes desirable a further analysis of their common and distinctive features, which will be undertaken in a later section. It should already be evident, though, that from these various sources there is general agreement that the specification of objectives can and should have a definite effect upon the design of sequences for auto-instruction.

Defining the Reinforcement Situation for the Learner

Most investigators of learning are agreed that some set of conditions which either follow or are coincident with the newly-acquired behavioral act serve the function of raising the probability that this act will occur again when the situation calls for it. This set of conditions is called reinforcement, and there is still no generally accepted definition of exactly what this set of conditions is, in a fundamental sense. Nevertheless, as used in connection with programmed instruction, there appears to be a procedure which is quite generally agreed upon, as to how this important set of conditions is put into use. The learner is required to supply a missing word, character, or phrase which will serve to complete a statement containing a blank. Having done this,

he is asked to look at a printed representation of this response, in order to see whether he has performed correctly. (He "checks the correctness" of his response). Evidently, what reinforcement means in programmed instruction, then, is that the learner matches a response production of his own to one he is told (or already knows) is correct.

Since this matching procedure is an integral part of the learning process, it does not seem unreasonable to suppose that giving the learner prior knowledge which enables him to circumscribe, or bracket, the variety of response which is expected of him, may have the effect of controlling the reinforcement and thus improving the efficacy of the learning which occurs. For example, in undertaking a multiple discrimination sequence, if the learner knows beforehand that he must distinguish the foreign words fin, femme, faim and fine, this may enable him to make the kind of match to printed reproductions of each of these words which is highly effective in a reinforcement sense. If he does not know this beforehand, he might tend to match fin with fine, and thus be receiving incorrect reinforcement. The frequent occasions in programmed instruction in which physically exact matches cannot be used to define correctness of response serve to emphasize the importance of this possiblity.

For these reasons, it has seemed to some authors that there is still a further reason for defining objectives, and that is to make them known to the learner, in order that he can carry out the matching procedure involved in reinforcement. In particular, this suggestion is to be found in the writings of Gagné (1963), who proposed defining objectives for the learner as a desirable first step in all instructional sequences, and of Mager and McCann (1961), who relate the notion more broadly to the idea of providing the learner with the capability of programming his own activities.

Effect of Specifying Instructional Objectives

Given the generally accepted importance of defining objectives, for whatever reasons, one might reasonably expect a fair amount of evidence for the efficacy of the procedure. In a sense, it may said that every demonstration of effectiveness of an instructional program constitutes such evidence, since the attainment of objectives in such a program means that they must have been well defined, as a necessary but not sufficient condition. But besides this, we need to seek out findings which show the effectiveness of specifying objectives in a rather direct fashion. The evidence of this sort is varied both in nature and in source.

An Example from Higher Education

The procedures of defining objectives described by Bloom (1956) have been tried out in a variety of colleges in connection with achievement testing and evaluation programs. A volume by Dressel (1954) summarizes the experience of thirteen different institutions of higher learning with the use of these techniques in a variety of different courses. Although quantitative data are not reported, one is impressed with the repeated occurrence of a similar sequence of events reported in many of these chapters, as expressed by Bloom (1954). Initially, the faculty were interested in improving the construction of achievement tests themselves. As they became better acquainted with the method, however, they began to realize the full import of Tyler's (1949) statement to the effect that examining has to be conceived as part of the total educational process.

The results of this realization were manifold and striking, it is reported. The faculty began to recognize the fundamental purpose of an educational program as one of changing the behaviors of students. They became increasingly skilled in relating their hopes for teaching outcomes to definable objectives. They began to question their own methods of

teaching and try out new ones. As for the students, they too became aware of objectives, and recognized a need for evidence about the extent of their progress toward these objectives. In all of these changes, one is ready to infer that teachers must have been improved, instruction must have been improved, students must have exhibited heightened achievement. It seems an unfortunate thing that the "evaluation" carried out by means of these procedures has not itself been evaluated in some controlled fashion. We are left, nevertheless, with the strong impression of instructional improvement.

An Example from Military Training

French (1956 a) reports an experimental study of the training of electronic maintenance personnel in troubleshooting. Forty apprentice mechanics for the K-System (an airborne bombing navigational system), who were graduates of a regular course of instruction, were given additional instruction in tracing the flow of information through the system, as exemplified in a number of equipment "problems." Half of the group received this type of instruction on an actual layout of the system, half on a training device called the MAC trainer. As measured on a test of system functioning, both groups showed a significant and marked increase in proficiency after seven and one-half days of instruction.

To gain the full import of this finding of improved performance, certain other facts need to be stated. First, the subjects in this experiment were considered to have been fully trained, as a result of having completed a standard course of many weeks in length. However, an analysis of objectives, carried out prior to the experiment (French, 1956 b) revealed that despite much instruction in "theory," the objective of capably performing troubleshooting on this system was not adequately represented in the standard instruction. The additional instruction,

making use of the MAC trainer, was specifically designed to establish student skill in making the decisions and carrying out the procedures involved in diagnosing malfunctions of the K-system. The results show that this instruction was effective in improving the performance of graduates of the standard course. They therefore demonstrate in a specific sense the importance of carefully defined objectives to the accomplishment of desired training outcomes.

Another example of improved performance resulting from instruction based upon a detailed specification of objectives, pertaining to a somewhat different type of Air Force maintenance training, is reported by Briggs and Besnard (1956). In this case, different training devices were employed in the establishment of identification responses, on the one hand, and check-out procedures, on the other, these having been identified as separate job-relevant objectives on the basis of a preceding analysis. Some additional examples deriving from military training are briefly described by Mager (1962).

Examples from Research on Programmed Instruction

Certain experimental studies of variables in programmed instruction pointedly demonstrate the importance of defined objectives to the effectiveness of the instructional enterprise. Falling in this category is the work of Gagné and his collaborators (Gagné, 1962; Gagné and Paradise, 1961; Gagné, Mayor, Garstens, and Paradise, 1962). As this method has developed, it has emphasized not only the terminal performance as something to be specified, but the analysis of this performance into entire hierarchies of supporting "subordinate knowledges," which of course are also performance objectives.

In a series of studies on various tasks of mathematics, it has been shown that the attainment of each of these "subordinate" objectives

by the learner is an event which makes a highly dependable prediction of the next highest related performance in the hierarchy. If a learner attains the objectives subordinate to a higher objective, his probability of learning the latter has been shown to be very high; if he misses one or more of the subordinate objectives, his probability of learning the higher one drops to near zero. In this view, the entire sequence of objectives, one building upon another until the terminal performance is reached is considered to be the most important set of variables in the instructional process, outweighing as a critical factor other more familiar variables like step-size, response mode, and others. According to these results, failing to achieve a subordinate objective, by whatever means this happens, means that the learner effectively "drops out" of the learning at that point, and is unable to acquire any higher-level knowledges. The implication is that when one sets out to design instruction having this hierarchical character, the specification of an entire sequence of objectives is essential to insure an effective learning program.

Another approach to the study of the effects of specifying objectives on learning is represented by a study of Mager and McCann (1961). Groups of engineers were trained in a number of different tasks pertaining to their jobs. In the initial group, the instructor controlled the sequence of content presented. In a second group, the students were permitted to select the content in accordance with an importance and a sequence they themselves assigned. In still a third group, the students were initially given a detailed statement of training objectives, illustrated by the kinds of questions he was to be expected to answer; in addition, they were permitted to instruct themselves in any order or by any means they wished, reporting to the instructor when they believed they were ready to demonstrate achievement of objectives selected by

themselves. The results of this study showed that time required for training could be reduced markedly (as much as 65% in the third group) without loss of proficiency. Although this experiment does not incorporate the careful control of conditions possible in a laboratory, its findings are too striking to be dismissed lightly. Clearly, these results pose the question: How much of learning (particularly of adults) could be accomplished simply by making the learner aware of learning objectives? If one set out to construct a self-instructional program containing a full set of stated objectives (terminal and subordinate), what else would be needed? These are challenging questions for those interested in understanding learning efficiency.

Identifying Objectives--Task Description

If objectives are to have this widely acclaimed importance in the technology of instruction, they must be clearly specified. But where do such specifications come from? What exactly is being described, and on what observations does this description depend?

Most authors have agreed that the statement of objectives must be based upon an "analysis." Perhaps the clearest and most consistent tradition of beginning to plan instruction with an analysis derives from research on military training, particularly the training of electronic technicians. In this tradition, the initial step has been called <u>task description</u>, and it seems reasonable to use this terminology here.

In describing what a man does in furthering the goals of any system, it is customary to describe these events as accomplishments (sometimes called "operations") like "putting a radar set into operation," or "computing amount of wind drift." The smallest convenient units of such accomplishments, such as "setting knob to zero," or "looking up the tangent of angle A," are designated as <u>tasks</u>. In theory, one can

conceptually reconstruct the entire set of operations to be carried out by any system, without any errors or misconceptions, by reading a properly prepared description which is given in terms of tasks listed in the correct order. It is evident, then, that descriptions of tasks must be complete, unambiguous, and reliable (in the sense that two readers would make the same prediction from them), in order to fulfill this function. Descriptions of tasks do not depict "raw behavior;" they do not, in a psychological sense, inform the reader what the human operator is "doing." Instead, they only state the accomplishment or outcome of the behavior, which is often called performance.

Task descriptions of this variety bear a close relationship to statements of instructional objectives. The latter are also descriptions of performance--one wants to know what the student will be able to accomplish after learning; not how he will accomplish it, but what. Similarly, it is desirable that statements of instructional objectives be complete--one wants to know all that the student will be able to accomplish; and unambiguous--there should be no misunderstanding of the denotations of the words employed. And above all, such objectives should be reliable, in the sense previously used--two readers should have no disagreement about the kind of performance expected of the learner. It may in fact be said that "describing instructional objectives" can be considered in all respects equivalent to "describing the (terminal) tasks" expected of the learner.

What characteristics must objectives, or terminal tasks, have, in order to meet these criteria? A number of attempts have been made to formulate an answer to this question, as noted in the following paragraphs.

Probably no one has written more extensively on the topic of task analysis than has Miller (1953; 1955; 1956a; 1956b). According

to a recent formulation (1961), the following elements are required in such a description:

(1) An indicator (or indication) is the signal for the beginning of the action. (Example: a light has come on).

(2) An action word, usually a verb and its qualifiers. (Example: push to right).

(3) A control, a physical object which the individual manipplates or otherwise acts upon. (Example: a toggle switch).

(4) An indication of response adequacy, another signal which tells the individual when his action is correctly completed. (Example: the click of the switch).

Evidently, a complete and reliable task description, using the examples given, would be: "When light comes on, push toggle switch to right until click is heard."

Can such a set of criteria be applied to the kinds of tasks which are more familiar in an educational framework? It is quite apparent that they can, and the exercise of doing so may be quite instructive. Suppose one tried to state whatever is suggested by "adding integers" as a task in Miller's terms. The result would be somewhat as follows: "Given the printed instruction 'add' and two integers (indicator), writes (action word) the symbol representing their sum (indication of response adequacy)." Of course, the use of a pencil (the control) is simply understood in this statement. Otherwise, it seems to be a perfectly good statement of an instructional objective! Consider another example, from the field of language: "recognizing similes in poetry." This might be expressed as follows: "Given lines of poetry such as "As a fond mother when the day is o'er...' (indicator), identifying (action word) in oral speech (the control) the essential items compared

as a simile, in the form, 'as ___, so ___' (indication of response adequacy.)" It seems evident from these examples that no important conflict arises in applying Miller's method of task description to the definition of instructional objectives.

It is of considerable interest to compare Miller's method and criteria for task descriptions with Mager's (1962) approach to the preparation of instructional objectives. Presumably, although each of these authors has faced a common problem of how to describe human performance, the backgrounds from which they approach the problem are somewhat different. According to Mager, the characteristics of a good objective description are as follows:

(1) A specification of the kind of behavior which will be accepted as evidence that the learner has achieved the objective.

(2) Description of the important conditions under which the behavior will be expected to occur.

(3) Description of how well the learner must perform to be considered acceptable.

One does not have to distort these statements to any great degree to be able to observe a considerable resemblance between these and the requirements stated by Miller. The first of Mager's points pertains to an "action word," externally observable. The second relates to the "indicator," and perhaps also to the "control," as conditions under which the behavior occurs. The third clearly identifies the "indication of response adequacy." It should be mentioned, however, that Mager gives an additional type of emphasis to the third of these points, namely, a quantitative one. For example, he considers that this criterion would be met by such a statement as "spelling correctly 80% of the words

called out to him during an examination period." But it is evident that he also accepts a meaning of "performance accuracy" which resembles the Miller notion more closely, as in "weighing materials accurately to the nearest milligram."

The fact that these two writers have independently arrived at criteria for task (or objective) descriptions which are so closely similar leads us to believe that they must both be right, and that the technique of description must be a straightforward and unassailable one. Summarizing their technique, we may say that instructional objectives can be described as tasks, the outcomes of human behavior. Such descriptions are designed to be understandable and reliable, so that different individuals are able from a reading of them to agree fully on a set of events which would constitute an example of each task. They contain the following kinds of terms:

(1) Words denoting the stimulus situation which initiates the performance ("Given two numerals connected by the sign +").

(2) An action word or verb which denotes observable behavior ("states").

(3) A word denoting the object acted upon, when this is not understood ("orally").

(4) A phrase which indicates the characteristics of the performance that determine its correctness ("the name of the numeral which is the sum of the two").

A final word may be added to the effect that there is general agreement that "action words" must be observable activities. This of course is important to the criterion of reliability, as defined here. To "know," to "understand," to "appreciate," are perfectly good words, but they do not yield agreement on the exemplification of tasks. On

the other hand, if suitably defined, words such as to "write," to "identify," to "list," do lead to reliable descriptions. There is nothing at all obscure about this distinction: it is simply one of a difference between actions which can be identified with agreement by several observers and actions which cannot be so identified. Acts which are overt are in the former category, without obvious exception.

Identifying Implications for Learning--Task Analysis

It appears from our preceding discussion that the technique of describing instructional objectives is fairly well agreed upon. But the next step, which is called task analysis, has neither been so fully developed nor so precisely specified. There are, in fact, various approaches to this problem.

The aim of task analysis (or the analysis of objectives) seems to be fairly clear, although this is not always apparent in the writings of those who have described such a technique. Once the performance expected at the termination of learning has been reliably specified, one needs to be able to draw some inferences concerning how these performances can be established most effectively. As Gilbert (1962) puts it, what is needed is to "prescribe a repertory of behavior structures.'" Involved in this aim must be the identification of classes of behavior which differ in respect to the conditions most effective for their learning. The optimal strategy for the attainment of a generalization, for example, is presumably not the same as the optimal strategy for the establishment of a multiple discrimination.

Approaches to Task Analysis from the Background of Military Training

Miller (1956b) undertakes to draw the differential training implications of several categories of tasks. It should be borne in mind that this work was done before teaching machines and their programming

requirements had had their impact on such analyses. Miller classifies behavior into the main categories of perceiving, recalling procedures, recalling nomenclature, interpreting, making logical inferences, and performing manual operations. Some of these categories, according to this analysis, can be taught by means of demonstrations, while others require verbal presentations, and still others are best learned by periods of practice on actual equipment. Obviously, this is a line of thinking which points in the direction of increasingly precise differentiation of categories of behavior having implications which can be distinguished as optimal conditions for learning. In a more recent formulation, Miller (1962) discusses the training implications of these and other categories derived from task descriptions in the following terms:

1. Goal orientation. The learner must be informed of the conditions and time of initiation of the task, as well as what the criteria of performance are.
2. Reception of task information. The learner must acquire responses which permit him to detect relevant cues; identifications of nomenclatures and actions; the filtering of signals through "noise."
3. Retention. Conditions need to be prescribed for the use of short-term retention; and practice will be needed for long-term retention of procedures and codes.
4. Interpretation and problem-solving. This kind of activity requires the learning of a variety of mediating activities, including classes of response options, response implications, goal priorities, and rules for selecting responses.
5. Motor responses. Practice sequences may be specifically designed to eliminate likely human errors, to avoid negative transfer, and to group responses into performance units.

Developing approaches to the problem of behavior categorization can also be seen in the writings of Gagné concerning task analysis (1955). Gagné and Bolles (1959) have proposed five major categories of behavior as training objectives, based upon an analysis of Air Force jobs. These are (1) identifying; (2) knowing principles or relationships; (3) following procedures; (4) making decisions about courses of action; and (5) performing skilled perceptual-motor acts. Each of these categories is conceived as having different training implications, not all of which can as yet be fully specified. Lumsdaine (1960) has undertaken to relate these same categories to the potentialities for training of various training devices and self-instructional devices.

In his most recent formulation of behavior categories, Gagné (1962) includes these formerly-described classes in three major ones, sensing, identifying, and interpreting. As represented in human tasks, each of these categories is conceived to generate a different set of requirements for its performance. These requirements apply not only to the conditions of learning, but also to the conditions immediately accompanying the performance itself, such as the stimuli displayed at the time of performance, and the verbal instructions which may be given to determine the conditions of "filtering" and "shunting" for the human performer (that is, the conditions under which the behavior will be expected to occur, cf. Mager, 1962). These categories and their differential implications may be briefly summarized as follows:

(1) Sensing, or indicating the presence or absence of a difference in physical energies. This behavior is not directly influenced by learning, but the capabilities of "filtering" may be learned, and the accuracy of reporting thereby improved.

(2) Identifying. Basically, this category may be described as making a number of different responses to a number of different classes of stimulation. This class of behavior is considered to be mediated by learned models (percepts and concepts), which also include the sequences of action occurring in procedures and in motor skills.

(3) Interpreting. In this class of behavior, the individual identifies inputs in terms of their consequences. Accordingly, the primary mediators which must be learned are rules or principles. With the most complex forms of interpreting, problem-solving, filtering rules, sometimes called strategies, may also need to be acquired.

Approaches to Task Analysis from the Background of Programed Instruction

Stolurow (1961) and Cotterman (1959) have formulated an answer to the problem of task analysis as a part of the principles of instructional programming. Their point of view, as recently summarized (Stolurow, 1961), clearly identifies as a criterion of task classification the question of whether a task characteristic produces an interaction effect with a practice (or teaching) variable. Accordingly, they identify a set of "critical learning task characteristics" which apply to the content of what is to be learned, where this is conceived as a variety of relationships between an S and an R. These dimensions of variation are considered to generate differential implications for the method of teaching (or programming) which may be summarized as follows:

(1) Number and sequence. The number of S-R's to be established strongly affects the ease of learning, according to previous evidence. So also does the length of the sequence of S-R's, and whether the sequence to be established is an invariant one.

(2) Limits of S and R. The extent to which variations are permitted in the stimuli and responses that define the task as well as the similarity of these components, will affect the ease of learning.

(3) Meaning. The orderability, the number of associations, and the associative significance of the responses are factors which may be expected to affect the learning of a task. There are many instances in which the learning of mediating associations facilitates the acquisition of the required responses.

(4) S-R linkage pattern. The nature of the linkage to be established by learning may be one-to-one (pairing object and name), one-to-many (genus-species relationship), many-to-one (species-genus), or many-many (a number of symptoms—a number of causes).

(5) S-R homogeneity and compatibility. Both S's and R's may be derived from a homogeneous class (such as English words), or they may not be. In addition, they may be compatible in the sense of increasing and decreasing at the same time, or not. Studies indicate that heterogeneity aids learning, and that compatibility does also.

It is evident that these categories of critical factors in learning are not at all to be considered "behavior categories," of the sort attempted by other writers. According to this approach, there are many varieties of behaviors; and in order to derive the specific implications each has for learning, one needs to consider the five sets of characteristics that each may possess. Stolurow's further discussion points out some of the relationships of learning conditions to these

characteristics, and emphasizes the problems which remain to be illuminated by research.

Gilbert's (1962) discussion of the problem of analyzing objectives again reflects the approach of identifying categories of behavior which imply different optimal teaching sequences. These categories are constituted by different sequencing of what Gilbert calls "the basic exercise model." This model is the minimal essential set of events which must occur for a new operant to be established. These are considered to be (1) an observing response, which leads to identification of (2) the S^D, the stimulus situation to be associated with the response; (3) another stimulus (S^I) which is able to call out the desired response; and (4) reinforcement provided by recognition of the end-product. With this as a basis, it is considered that three major categories of prescription for teaching may be made, each of which is independent of specific content.

(1) Chains of behavior are best established by "retrogression through the basic exercise model;" in other words, by a means of a sequence which works backwards from a terminal response to the observing S-R which begins the chain.

(2) Multiple discriminations are exemplified by instances in which different responses have to made to an equal number of different stimuli. This kind of behavior is particularly subject to competition (interference), which may be overcome by judicious use of induction (facilitation of similarity) and by mediation (a process of chaining utilizing an existing verbal operant of high strength). Gilbert argues that a multiple discrimination is best established in one exercise.

(3) Generalizations occur when classes of responses (like the counting of alphabetic positions in an alphabetical file) must come under control of classes of stimuli (like all spaces between names, in such a file). Generalization teaching is required whenever it can be estimated that two separate instances of the stimulus, as different from each other as possible, would not serve as direct substitutes for each other in controlling the desired response.

Task Analysis from the Standpoint of Education

Tyler (1949) states the second step in curriculum construction as selecting "learning experiences that are likely to attain the chosen objectives." Such selection, he says, should be in terms of the probable usefulness of the learning experiences in reaching the desired goals, as guided by studies of learning conducted in the psychological laboratories and in schools.

Following the leads suggested by Tyler's writings, a committee of College and University Examiners of the University of Chicago undertook to describe a taxonomy of educational objectives, and these are collected in a volume edited by Bloom. Six major categories of objectives, each containing a variety of subcategories, is described. The six taken together are considered to constitute a hierarchy, in which the objectives in the later classes are likely to make use of (or build upon) those in the earlier ones. A summary of these categories is as follows:

1. Knowledge. This category is measured by tests requiring the recall of specific and universal facts, methods and processes, patterns, structure, or settings. The examples indicate that the class includes the recall of specific identities, of verbal statements, and of abstract concepts.

2. Comprehension. This class includes translation (supplying equivalent responses for previously acquired identifications), interpretation (formulating a statement representing a set of events), and extrapolation (predicting consequences of courses of action).
3. Application. Applying general principles and abstract concepts to specific novel situations.
4. Analysis. Distinguishing the kinds of elements in a communication, such as facts and hypotheses; recognizing the facts and assumptions essential to a major thesis, and distinguishing relevant from irrelevant statements; identifying general form, pattern, purpose, or other organizing principle.
5. Synthesis. Producing a total communication, plan, or set of operation, given the essential components.
6. Evaluation. Making reasonably accurate judgments of value, accuracy, consistency, or correspondence with certain criteria.

On the whole, the categories described by Bloom provide a highly informative picture of the variety of kinds of human performances which may reasonably be expected in an educational setting. They therefore represent a genuine challenge to those who wish to define the objectives of instructional programs, and apply them to education at all levels. It is also quite apparent that these statements fail to meet the criteria of task description described by Miller and Mager. In particular, they provide inadequate information about what Mager calls "the important conditions under which behavior will be expected to occur." For example, what does "recall of specific facts" mean? Can it, or can it

not, be phrased as "supplying a word or phrase which will correctly complete a verbal statement?" Many other examples of this sort, exhibiting equal or greater degrees of ambiguity, can readily be identified in this work. It appears likely that a first step in improving the usefulness of these statements would be a "translation" into other statements which satisfy the criteria previously discussed.

As categories of behavior, the classes described by Bloom are likewise not entirely adequate. For one reason, some of the subordinate classes described are distinct from each other only in terms of their specific content, rather than in terms of formal characteristics which affect their learning conditions. "Knowledge of terminology," for example, may not be formally distinct from "knowledge of classifications and categories;" similarly, "knowledge of conventions" appears to be highly similar in a formal sense to "knowledge of principles." Unfortunately, too, it is not clear that these similarities of formal characteristics do not apply even across major categories, as when "knowledge of generalizations" is distinguished from "interpretation" (comprehension) and both of these in turn from "comprehending the interrelationships of ideas" (analysis). The test items used to illustrate each type of statement are indeed valuable in providing objective meanings for these phrases. But the objectives described here cannot be successfully employed, as they stand, for the derivation of distinct classes of behaviors for which optimal learning strategies can be specified. As suggested previously, a reformulation of these objectives, using the test items as a basis, might yield an extremely valuable product.

The Design of Optimal Conditions of Instruction

As the previous discussion indicates, the relation between categories of instructional objectives and categories of optimal conditions

for learning has been recognized for many years, and approached from several different angles. Although there are differences among these approaches, there are also striking similarities. To consider the latter in detail would perhaps not be the most fruitful exercise to engage in, for the purposes of the present chapter. Therefore, the attempt will be made instead to make another formulation of behavior categories, which is hopefully comprehensive, and which can be related at every point to the suggestions of previous writers. In the case of each category, the question to be addressed is, what are the conditions which specify (so far as is known) optimal conditions for learning the tasks that involve this kind of behavior?

Response Differentiation

A basic form of learning, which appears to be prerequisite for all other forms, has been called response learning or response differentiation. According to Skinner (1957) the simplest case in which verbal behavior comes under the control of verbal stimuli is to be found in echoic behavior, in which the response generates a sound-pattern similar to that of the stimulus. When a young child learns to say "daddy" to the stimulus supplied by a parent "Say daddy!" the child's response produces a sound which occasions reinforcement. The stimulus "daddy" is of course a discriminated stimulus, since the child learns not to make this same response in the presence of other stimuli like "Say mama!." Furthermore, the sound produced by the child himself now becomes a discriminated stimulus for the response, as evidenced in babbling. One can then speak of this response (or more precisely, this act) as having become differentiated, since a given stimulus is dependably followed by a response that sounds like the stimulus, whereas other stimuli do not have this outcome.

While the learning of echoic behavior may be the most frequently occurring basis for learning of verbal behavior in human beings, it is not necessarily the only type that may be called response learning. In non-verbal behavior, discriminated stimuli other than verbal ones may come to control responses in just as dependable a fashion, and these too can become the basic links in the learning of other kinds of behavior.

It is of interest to note that response learning, while usually too simple a form of behavior to be treated separately as an objective of instruction, is often mentioned as a prerequisite to other learning. Gilbert (1962) states that the basic operant on which any chain is established must be a "strong" one in order that another act can be linked to it in what he calls the basic exercise. Modern methods of teaching foreign languages also frequently make use of response differentiation of the sounds of the unfamiliar language as a basic step in the establishment of speaking and comprehension skills. Additional discussion of this point is contained in the chapter by Lane. The work of Underwood and Shulz (1960) demonstrates the great importance of "response availability," "familiarity," or "pronunciability" to the learning of verbal paired-associates. Studies by Saltz (1961) and McGuire (1961) suggest that response familiarity is probably a matter of response differentiation, and it is evident that this in turn may be brought about when the stimulus forms of these responses come to function as discriminated stimuli in an echoic manner. Mowrer's (1961) discussion of the acquisition of speech by animals also includes the idea that speech sounds must be discriminated as sounds before being associated with other signals. Again, in human language training, the learning of correct speech has been shown to depend critically upon the discrimination of speech sounds as stimuli (Holland, 1960). All these lines of evidence show

the importance of response learning as a pre-condition of other forms, and further suggest that response availability is brought about when the stimulus effects of the response become an S^D for the response itself.

Assuming reinforcement to be the basic condition for all learning, there is only one other condition which appears to be required for response learning. This is contiguity, in the sense that the R must occur within a few seconds after the S. As has been said, the stimulus "Say daddy!" must be followed closely in time by the response "daddy" on the part of the learner. It is possible that a single repetition involving contiguity of this sort will accomplish the learning that is sought. In any case, the long-continued controversy about the continuous or non-continuous nature of learning cannot be reviewed here.

Associations

There are many human tasks whose acquisition requires the learning of what has traditionally been called an association. In using the term here, there is no intention of naming a mechanism, neural or otherwise, but simply to describe the observation that a stimulus (S) comes to be "associated" with an individual's response (R) in such a way that the occurrence of S is followed by R predictably with a high probability. When a child acquires a new word naming an object, he has acquired an association; and the same is true for an adult, if the object is a new and unfamiliar one. Acquiring new technical words, or new words in a foreign language, are other well-known examples. Of course, responses other than verbal ones may be involved in associations, as when an individual learns to press a new button on the dashboard of an unfamiliar automobile. Instructional programs are often concerned with the teaching of new words, new associations.

It is important to mention at the outset that what must be learned is often more complicated than a simple association. In particular,

one thinks of the situation in which the individual must not only learn to say le bras to the stimulus "arm" but also la jambe to the stimulus "leg," and le main to the stimulus "hand." As soon as the possibility of confusion exists among stimuli, the behavior becomes that of multiple discrimination, which is to be discussed in the next section. But one must consider first the simplet situation, in which such possibilities of confusion do not exist. In addition, it is apparent that the simple association hand - le main must be itself learned, regardless of whether or not it is later found to exhibit confusion with some other association. Many foreign words may be acquired under conditions in which little confusion is evident, as for example, cheese - le fromage.

Although association learning was for many years treated as though it involved a single S-R event, it is now widely accepted that three separate parts make up an association, each of which can be subjected to different learning conditions (McGuire, 1961). What this means, actually, is that an association is a three-member chain, a form of behavior to be described more extensively in a subsequent section. For an association to be established most readily, there must first be discrimination of the S from the surrounding situation in which it is embedded. Im other words, the S must become an S^D. Gilbert (1962) points out that this condition is a prerequisite for the "basic exercise." Typically, a stimulus is used as a part of verbal instructions to call out an observing response (R^O), which leads the learner to locate and respond to the S^D.

The second condition is one of response availability, occasioned by preceding response learning, as previously mentioned. When a new word is being taught, one should insure that the echoic behavior $S^D_{fromage} - R_{fromage}$ is well established before attempting the association $S^D_{cheese} ------ R_{fromage}$. The findings of Underwood and Shulz (1960) regarding this point have previously been cited.

The third condition pertains to the pre-existence (or previous learning) of a "coding" response, usually not exhibited in overt behavior, which becomes a link between the response occasioned by the initial stimulus and the following stimulus that controls the desired reponses. In other words, the "code" is the central member in the paradigm:

$$S_{RED} \text{-----} r_{rose} \cdot s_{rose} \text{-----} r_{flower} \cdot s_{flower} \text{-----} R_{FLOWER}$$

There is considerable evidence that the stronger has this "word association" act been made by previous learning, the more rapidly will the learning of the desired association take place (Deese, 1961).

In its purest form, then, association learning requires the previous acquisition of (1) a discriminated stimulus, (2) a differentiated response, and (3) a coding act which can become the middle part of the chain. When these conditions are met, the learning of an association appears to be a very simple matter involving contiguity of the S^D, the coding link, and the R. An association like <u>cherie</u> - <u>dear</u> can be assumed for practical purposes to be learnable when the contiguous S-R events occur on a single occasion.

<u>Multiple Discrimination</u>

This form of behavior, which Gagné (1962), among others, calls <u>identification</u>, requires that the individual make several different responses to an equal number of stimuli. In the language of task description, he "distinguishes" or "differentially identifies" two ormore physically different stimuli. As an example, one may take the task described by Gilbert (1962) of identifying the ten different colors of resistor bands with the numerals 0 through 9. Many other examples come to mind immediately: the identification of unfamiliar words, the acquiring of a foreign language vocabulary, the distinguishing of locations and names of instruments on a panel.

It is evident that the individual acts that constitute multiple discrimination behavior are associations, and must therefore basically depend upon the conditions already described for the establishment of these. If a single identification is to be acquired, which is already distinctive and which generates no confusion with other activities, the behavior is simple association. But there are few enough instances of this sort in real life that special pains must be taken to select such instances for experimental study. More usually, the possibilities of confusion abound. One must not only associate faim with "hunger," but also femme with "woman," and the two stimuli sound very much alike when received aurally.

For many years it has been recognized that the event which most clearly governs the learning of multiple discriminations is interference, that is, the tendency for the individual associations involved in identification behavior to get "mixed up," so that the stimulus for one tends to call out the response for another, and vice versa. The basic rationale has been described by Gibson (1940), and has in general withstood the test of time and much experimentation (cf. Underwood, 1961). From the standpoint of an optimal learning prescription, the various findings may be summarized as follows:

Make the stimuli as distinctive as possible. The evidence is clear from paired-associate studies that the rapidity of acquiring multiple discriminations increases directly with the degree of distinctiveness (lack of confusability) of the members of the set being learned (Underwood, 1953).

How does one go about making the stimuli of a task more distinctive? Three main methods have been used. (1) The first involves adding distinctive cues to stimuli during learning, which are later "faded" and "vanished" (Angell and Lumsdaine, 1962). (2) A second method, and

an extremely effective one in many situations, is to use mediation (Gilbert, 1962, p. 57). A stimulus like the color brown may be linked to a response like "penny," already at high strength. This in turn is associated with "one," the required response. At the same time, the stimulus "black" may be linked to "nothingness," which in turn is associated with "zero." As Gilbert shows (1962), this procedure can be effectively applied to all ten resistor colors. (3) A third method is to group stimuli which are highly similar, and whose responses possess elements in common, thus capitalizing upon induction (or stimulus generalization, as it is often called).

Should the responses in multiple discrimination behavior also be made distinctive? The answer to this question is yes, if what is meant is making the responses highly available, by discriminating them as stimuli, as previously discussed. In many cases of multiple discrimination, the responses may be assumed to be highly available, as is the case with the numerals zero through nine in Gilbert's example. No purpose would be served by attempting further to differentiate them. However, if new words are being learned (as is the case, for example, in paired-associate studies using nonsense words), there can be little doubt that pre-discrimination learning of these responses represented as stimuli would have a facilitating effect on learning (cf. Gibson, 1942; Cannon and Noble, 1961). In terms of the present discussion, response availability is assumed as a pre-condition of multiple discrimination learning.

If there are, say, ten associations to be differentiated in a multiple discrimination, the question of sequence of presentation obviously arises. Should they be presented in instruction one at a time, two at a time, or even all at the same time? Gilbert (1962) argues for the

effectiveness of an "all at once" presentation, using mediation. With ten or fewer differentiations to be learned, this method may often be practically useful. However, a general answer to the question of sequence must certainly consider the problem of more than ten individual associations. There does not appear to be clear evidence which would make possible a general prescription at the present time. Two additional possibilities should be given serious consideration in research on this question of learning sequence for multiple discrimination learning. One is the advantages of various part-whole arrangement (McGeoch and Irion, 1952, pp. 499-507), and another is the effects of grouping of similar and dissimilar stimuli (Gagné, 1950; Rotberg and Woolman, 1963).

Multiple discrimination learning, then, requires that two or more individual S-R associations be distinguished and freed from interference. Optimal conditions for such learning begin with the assumption of (1) response availability (differentiation) and (2) association of the individual S-R's, as prerequisites. The tactics to be employed are concerned with making the stimuli of the task as distinctive as possible. Methods of accomplishing this include the use ofmediating responses, addition of cues for stimuli which are then progressively "vanished," and grouping of stimuli to reduce the effects of stimulus generalization (induction). Sequence of presentation of the individual associations may also have an important effect on the interference generated in such learning.

Behavior Chains

Another way in which single associations may be put together is as behavior chains. Gilbert (1962) discusses chains and sub-chains at some length. Gagné (1962) calls them sequences, and notes that they often occur within tasks commonly identified as procedures. Certainly

behavior chains are very common; examples are computational procedures of mathematics or of accounting. Adding fractions, for example, is an activity which may be described as a sequence including (a) finding the lowest common denominator; (b) multiplying individual fractions by a factor; (c) adding numerators; and (d) dividing numerator and denominator by a common factor. However, in designing instruction for this activity chain, one might well need to break these steps into smaller ones, in order to insure that each step is within what Gilbert calls the "operant span."

In pure case, the learning of a behavior chain is a matter of putting together in prescribed order a set of previously learned individual associations. One would expect in this case to find many results having applicability to this problem from studies of serial verbal learning (McGeoch and Irion, 1952). For a number of reasons, however, this does not appear to be the case. It is now fairly generally recognized that serial verbal learning represents a mixture of several different kinds of behaviors, including response learning (Underwood and Postman, 1962), association learning (Primoff, 1938; Young, 1959), and the learning of order. It is therefore difficult to separate the influence of independent variables on these behaviors, in terms of the measurements of learning employed. What the results do emphasize is simply this: the determination of optimal conditions of learning an <u>order</u> of things must depend upon the assumption that these "things" have already been individually learned. This means, as our previous discussion implies, that the establishment of behavior chains (in its optimal form) requires the pre-learning of (1) the individual associations that make up the chain, and (2) any multiple discriminations that may be required to prevent interference among the stimuli in the chain (which tend to make otherwise correct responses occur in the wrong order).

The prescription of establishing chains retrogressively, described by Gilbert (1962), apparently has no clear precursor in the literature on serial verbal learning, despite the long history of such research. It is based on animal learning, particularly the chaining of operants (Findley, 1962), and upon the concept of reinforcement. According to Gilbert's statement of this idea (1962, p. 21) if the consequence of a response is reinforcing, the occasion for this response will be reinforcing, and any operant which produces that occasion will be strengthened. Accordingly, if one sets out to establish a chain, in an optimal fashion, he would begin with a final (reinforcing) act, and then proceed to associate it with the next preceding act in the chain. Once this has been done, the new act itself acquires reinforcing properties, and may then be associated with another new occasion, and so on back to the beginning of the chain. This method has a definite intuitive appeal as a programming technique. Further exploration of the conditions under which it may operate with greatest effectiveness would be valuable. In addition, consideration might be given to investigating the relation between "backwards chaining" and the "forward-looking objective" proposed as an initial frame in instructional sequences (Gagné, 1963).

Class Concepts

It is generally recognized that many responses made by a human being serve to identify, not specifically denotable objects (such as a particular switch, or a particular French word), but classes of objects or events, the stimulus characteristics of which may vary widely. Such classes include not only categories whose physical features seem to have a "prototype" identity, like chairs, birds, automobiles, etc., but also those categories whose membership may be infinitely variable, like "the upper one," "the middle one," "the odd one," "a space," and many others.

Obviously, it is not a difficult task for a human being to "choose the odd one;" for a monkey, it is initially quite difficult (Harlow, 1949).

Systematic research on how such concepts are learned by human beings has struggled for years against the difficulty of formulating the problem, as well as how to go about studying it (cf. Gagné, 1959). In all probability, the best clues to the understanding of this kind of learning will come from studies of children who do not yet know what word like "odd" or "upper" means. In the case of adult human beings, however, it is usually clear that they do know what such words mean, and that the problem of "concept acquisition" is not for them a problem of learning, but merely one of reinstatement. Accordingly, the basic operation involved in instruction which establishes a class concept is in fact instructions such as the sentence "choose the odd one."

Beyond this, it may also be noted that a possible meaning for "learning a concept" in an adult is "learningthe limits of generalization of a concept." A concept like cell has a meaning in biology which has more or less specific limits. Some things observed through a microscope are not cells, while others, although widely different in physical appearance, are cells. One would like a biology student to be able to identify a cell correctly throughout a very considerable range of variation in physical appearance of this object. Accordingly, learning the concept "cell" may be seen to be a matter of learning to generalize the correct identification among a suitable variety of stimulus situations. So far as is known, the best prescription for such instruction is to establish such identifications (in the manner described in a previous section) in a representative variety of situations. Gilbert's (1962) discussion of the problem of generalization learning is consistent with this account.

As is true with other forms of behavior, the learning of class concepts can be seen to have some pre-conditions. The response itself (such as "cell" or an unfamiliar one, like "nucleolus") must be differentiated. And at least one association must be established, before generalization learning can proceed. Following this, multiple discrimination learning can be undertaken with each stimulus sample selected, in order to establish the concept fully.

Principles

The acquisition of "principles" or "rules" is perhaps the most common form of learning undertaken by means of an instructional program. Principles are involved in learning to spell ("i before e except after c"), to handle sentence structure ("the pronoun agrees with the noun subject"), to divide fractions ("invert one fraction and multiply"), to determine the date of federal elections ("first Tuesday following the first Monday in November"), and, in fact, in almost every conceivable subject to be taught. It has occurred to some scholars that perhaps principles are the only things which can reasonably be programmed in instruction. But this is not so, as previous paragraphs have shown. In addition, such a view runs the danger of overlooking the fact that the learning of principles is based upon simpler forms of learning, and that the latter may therefore be required to be directly involved in any particular instructional sequence.

Formally described, a principle is a chain of two concepts (Gagné, 1963). Actually, a chain may be longer than that in the sense that it contains some sub-chains; but it is convenient to consider the essential aspects of a principle as exhibiting two links. In common language, a principle can be stated in the form "If a, then b," where a and b are two concepts. Examples are: if (a) the temperature of water is above 212 degrees, then (b) boiling occurs; if (a) the numerator is larger

than the denominator, then (b) divide the former by the latter; if (a) a diphthong is composed of i and e, then (b) the second letter is pronounced.

Are principles inevitably verbal? Certainly not. It is not intended here to suggest that in order to pronounce the diphthong "ie" the individual must say to himself verbally, "when i and e occur in a diphthong, pronounce the second letter." The exact composition of what the individual "says to himself" need not be known, perhaps cannot be known. All one needs to know is that the task can be performed, and that it can be done with any letters of the class i and e, and in any context of surrounding stimulation. One does not know what the mediation of such tasks is, and whatever it is undoubtedly varies among individuals.

In order to describe and communicate what the individual is doing, however, it is completely inadequate to say that the individual "makes the response $\bar{e}$ to the stimulus ie." (It is not denied that the individual may conceivably be doing only this, but in that case, it is an inadequate objective for learning). In performing a task according to a principle, the individual is reacting to the class of "ie and e combinations" by pronouncing the class of "second letters." As a matter of convenience, one can describe these classes and their chained relationship in a verbal phrase of the form "If a, then b." This is the way a principle is described, but not necessarily the way it is learned.

There are however some very important pre-conditions for the learning of principles. Outstanding among these is the condition that the concepts which make up the principle must be previously acquired, in order for learning to occur most readily. Gilbert's example of a principle (1962, p. 54) provides a good illustration of this point. The principle pertains to the operation of filing, and is as follows: "All spaces between filing reference names, count as one alphabetic position weighted

less than A." As Gilbert's discussion implies, such a principle cannot be learned unless the individual has learned the generalized meanings (i.e., the concepts) of "filing reference names," and of "alphabetic position," as well as "weight less than A." While it is possible, of course, to teach the two parts of a principle all at the same time, such a procedure does not permit the separation of "concept learning" from "principle learning," and accordingly does not make possible the specification of optimal conditions for the latter as is attempted here.

If one assumes that both parts of a principle have been previously learned as concepts, it is a fairly easy matter to bring about the acquisition of the principle. It may be desirable before actually suggesting the order of events in the chain, to insure that each concept is highly "available" and can be recalled readily. A frame devoted to review may be used to accomplish this purpose (cf. Gagné, 1963). Following this, it is a matter of getting one link of the chain to become the occasion for the other, so that the sequence becomes established. In all probability, it is of particular importance in this situation to encourage the learner to make a "constructed" rather than a "copying" response.

Strategies

Are there forms of behavior which are more complex than principles? First of all, it may be noted that rules themselves can get pretty complicated, without departing in any important way from the basic structure already described. There may even be "higher-order rules," which are composed of two or more "simpler rules" (Gagné, 1963). But some authors seem to imply another form of learned organization in the strategies with which an individual approaches a task or solves a problem (cf. Bruner, 1961). The existence of such strategies, in fact, appears to be well established (Bruner, Goodnow, and Austin, 1956). It seems reasonable to

consider that strategies are mediating principles which do not appear in the performance of the task itself, but which may nevertheless affect the speed or excellence of that performance. If this be so, then obviously one has to use rather special methods to uncover these strategies, and in that sense they may exhibit a different "form." But it is also possible to conceive of them as having principle-like qualities, and of being made up essentially of a chain of concepts. Such strategies as "choose the odd except when the light is on the left," or "choose the alternate keys in order," or "alternate every third choice" are, after all, principles which can readily be analyzed into their component concepts.

If strategies are really principles, then they obviously can be learned as principles, and no new specifications for their learning are needed. It may be well to emphasize again, however, that strategies (considered as principles) imply the learning of their concepts as a prerequisite condition. If one is going to be able to learn the strategy "first match the borders in curvature," he must already have mastered the concepts "borders" and "curvature." If he has learned these, the learning will be easy. If he has not, then it is difficult to say what is happening, since one individual may have to learn the concepts while another may not, while both will need to acquire the principle. From the present point of view, therefore, to conduct an experiment of this latter sort is to conduct an uncontrolled experiment.

Recapitulation - Behavior Categories

The preceding discussion has attempted to identify six main categories of behavior which exhibit formal differences among themselves, irrespective of content, but with respect to the conditions required for their most rapid acquisition. Such differences in learning conditions

have an obvious relation to the tactics used in designing instructional programs of greatest effectiveness. It has been emphasized that one large and important class of "learning conditions" includes those we have called pre-conditions of the learner, that is, they must be assumed as previously established behaviors of the learner ("entering behaviors"). The other major class comprises those conditions which obtain within the confines of any particular instructional sequence. These ideas are summarized in Table 1. (next page)

Viewing the process of instruction from the standpoint of this table, one is inclined to emphasize several implications:

1. Designing optimal-instruction is a matter of choosing the proper tactics for each of six categories of behavior implied by the formal (non-content) characteristics of instructional objectives (tasks).
2. Any set of instructional objectives may require one or more, or any combination of these tactics to insure that learning occurs most effectively. An excellent description of this problem and its complexities is given by Gilbert (1962).
3. For each type of behavior shown, the process of learning in its pure form is exceedingly quick, and depends mainly upon the contiguous occurrence of certain stimulus and response events.
4. The impurities in learning, which occasion slowness and difficulty, are largely attributable to insufficient pre-conditioning of the learner, so that more than one kind of behavior has to be acquired at one and the same time. Since optimal conditions for learning are different for each type, this results in ineffective tactics.

TABLE 1

Categories of Behavior Differing in Formal Characteristics
Relating to Ease of Learning,
Including (1) Pre-Conditions of the Learner, and
(2) Conditions of the Instructional Situation

Behavior Category	Behavior Description	Pre-Conditions of the Learner	Conditions of Instructional Situation
Association	Specific stimulus occasions a particular response	Discrimination of stimulus by observing response; differentiation of response	Contiguity of S and R
Multiple Discrimination (Identification)	Two or more specific stimuli call out an equal number of different responses	Individual associations; differentiation of responses	Make the stimuli highly distinctive
Behavior Chains (Sequences)	Two or more acts to be completed in a specific order	Individual associations; multiple discriminations among members of the chain	Begin with high-strength acts, associate these with low-strength acts in order
Class Concepts	Responses made to stimuli of a class, differing in appearance	Individual associations; multiple discriminations as necessary	Present sufficient variety of stimuli to insure generalization
Principles	Chaining of at least two concepts: if a, then b	Concepts	Insure availability of concepts; encourage constructed responses
Strategies	Chaining of concepts	Concepts, not represented in task	ditto

The Objectives of Retention and Transfer

It is not uncommon for descriptions of instructional objectives to include aims such as retention of performance over a specified period of time, and transfer or "application" of the behavior that has been learned to new situations. It may be recalled that indications of concern with these kinds of events have already been noted in the categories proposed by Miller (1956), one of which is "recall," and even more prominently in those described by Bloom (1956) which includes "application" as a major class. It is worthwhile to consider here whether these two kinds of objectives imply any different or additional tactics for the design of optimal instruction.

Retention. The results of studies which have undertaken to measure retention of programmed instructional materials are remarkably similar in some respects. First of all, they tend to show high amounts of retention over periods of weeks and months (Gagné and Dick, 1962; Alter, 1963; Glaser and Reynolds, 1963; Gagné and Bassler, 1963). Second, they report high degrees of correlation between achievement measured immediately following learning and after a longer retention interval. Of some relevance to the question of instructional objectives is the fact that few relationships have been demonstrated between independent variables in effect during the learning period and the later retention scores. Thus, Alter (1963) finds no significant differences in retention related to differences in initial achievement, or in rate of retention as affected by intelligence scores or rate of program completion. Glaser and Reynolds (1963) report no differences in retention associated with a number of variations in amount of repetition and the spacing of reviews. Gagné and Bassler's (1963) results fail to reveal differences in rentention associated with amount of repetition of sub-task examples, or of a time separation between the completion of one sub-task and the introduction of the next.

Thus these results provide few hints as to the possible differential effects of task differences on the retention of materials acquired by programmed instructional methods. Nevertheless, one cannot dismiss lightly the possibility that such differences may be found, if direct attempts are made to study them. From the point of view of the present discussion, the important question is, can differences in retention be found for the various behavior categories of association, multiple discrimination, behavior chains, class concepts, principles, and strategies? The answer to such a question requires the conduct of experimental studies which deliberately set out to deal with the acquisition (and retention) of relatively "pure" forms of each of these behaviors in isolation from others. This form of experimentation has not as yet been carried out within the tradition of programmed learning. Previous findings in verbal learning (McGeoch and Irion, 1952) probably have some relevance, insofar as they reveal differences in retention for paired nonsense syllables (multiple discrimination), verbal sequences (behavior chains), and logically-connected ideas (principles).

Transfer. In a manner similar to retention, one can ask whether there are differences in transferability of the behaviors of association, multiple discrimination, chains, concepts, and principles. However, it is at once apparent that instructional objectives enter into the question in a definitional sense.

In the case of association and the two forms of behavior which represent direct elaborations of it, multiple discrimination and behavior chains, the objectives of instruction are opposite to those of transferability. In each of these instances, the aim of instruction is to produce mastery of tasks which require specific response outcomes to stimuli having specific physical identities. In stating the required outcome of an association such as boy-happy, for example, the response "joyful" would be considered

incorrect by the experimenter; similarly, the response "happy" would be called an error if made to the stimulus "youth." Multiple discriminations also have this characteristic, since their learning is undertaken primarily to overcome the tendencies to generalization which may occur among members of the set of stimuli to be discriminated. Accordingly, it may be said that the criterion of transferability is a negative one, so far as the objectives represented by these forms of behavior are concerned.

But the situation is quite different for class concepts and principles. As has been pointed out previously, these forms of behavior are established by conditions which foster generalizability. Furthermore, it is necessary to state the objectives of instruction for these behaviors in terms which will clearly distinguish them from simpler forms such as associations and multiple discriminations. This is the reason for using the word class in task descriptions comprising the former kinds of behaviors. The learner acquires responses to stimuli of the class "left," "right," "opposite," "noun," "fraction," or whatever. Or he acquires a principle which chains the class "subject" with the class "sentence;" the class "numerator" with the class "fraction." In such instances, transferability is a part of the instructional objective, rather than being specifically excluded from it.

There is, then, an immediately apparent difference in objectives of instruction between the "simpler" forms of behavior, association, multiple discrimination, and behavior chains, and the more "complex" forms, concepts, principles and strategies. The former imply an absence of transferability (generalizability), whereas the latter require its presence. Beyond this, there are some intriguing research questions which remain to be investigated. For example, the extent of generalization which should be used in instruction on concepts and principles, in order to insure

transferability, has not yet received a clear specification (cf. Gilbert, 1962, p. 54). There is also the important question of what implications for subsequent learning may result from the inadequate transferability of concepts and principles, which may have been acquired under conditions of inadequate generalization in the first place. Answers to these and other related questions will add much to our knowledge of how to specify tasks to be learned.

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